WRP Technical Note HY-IA-2.1
May 1994

Harmonic Analysis Can Assess Hydrologic Cumulative Impacts

PURPOSE: This technical note describes an aid for assessing cumulative impacts on wetlands. Harmonic analysis techniques are employed to reveal time-frames when disruption to basic flow patterns may have occurred.

BACKGROUND: Water-level patterns largely determine the nature of wetlands. Therefore, studies of historic water trends associated with wetlands should explain causes-and-effects operating on wetlands and the resulting landscape/ biotic composition. Keys to characterizing historic water-level trends are called "hydrologic indices."

SIMPLE INDICES SAMPLE: Hydrologic indices may be categorized as either simple or complex. Simple indices are easy to compute and include parameters such as mean, median, and range of flows. However, these indices often fail to describe adequately periodicity, seasonal behavior, or evolution of stream character resulting from land-use changes and channelization.

Despite obvious limitations, such simple indices can reveal important features of streamflow and how those parameters compare with those of other streams in the same basin. These simple indices can also give clues regarding the timing of historic, momentous events, such as the abrupt decrease of the monthly maximum flow in the Little Red River record (1961) shown in Figure 1 with records of other selected streams in the White River Basin (Arkansas/Missouri).

The effects of more subtle but perhaps no less profound impacts may be better detected and quantified using indices that are somewhat more complicated to derive but which may yield more insight into cumulative impact analysis. One such index investigated, harmonic analysis, is given here. Another index, time scale analysis, is treated in WRP Technical Note HY-IA-2.2.

HARMONIC ANALYSIS INDEX: Harmonic analysis can show not only periodicity but also the change of a stream's character ("flashiness," ratio of minima to maxima and means, etc.) over time. This index reveals seasonal aspects typical of streams where flow responds to snow melt, summer drought, and other seasonal events.

The flow record of the Cache River at Patterson, AR was examined using harmonic analysis. This record included partial or complete flow records for the years 1928 through 1931 and 1938 through 1989. In addition to stream gage records, this river and its basin have extensive historic land-use records as well as data gathered by the various remote sensing methods. Flowing through a wetland designated as one of profound importance (Kleiss 1993), studies of its hydrology and landscape ecology are ongoing. Therefore, new analysis techniques have a high potential for validation. Harmonic characteristics of the flow history of the Cache River are illustrated in Figure 2.

- The mean for each month in each time period ("decade") represented by the gage at Patterson, Arkansas, was determined. Because the record from 1921 through 1940 was available for only 12 years, this period was considered a "decade" for the purposes of this study.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **MAY 1994**	2. REPORT TYPE	3. DATES COVERED **-**
4. TITLE AND SUBTITLE **harmonic Analysis Can Assess Hydrologic Cumulative Impacts**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Army Engineer Waterways Experiment Station,3909 Halls Ferry Road,Vicksburg,MS,39180-6199**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
see report

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**		**10**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

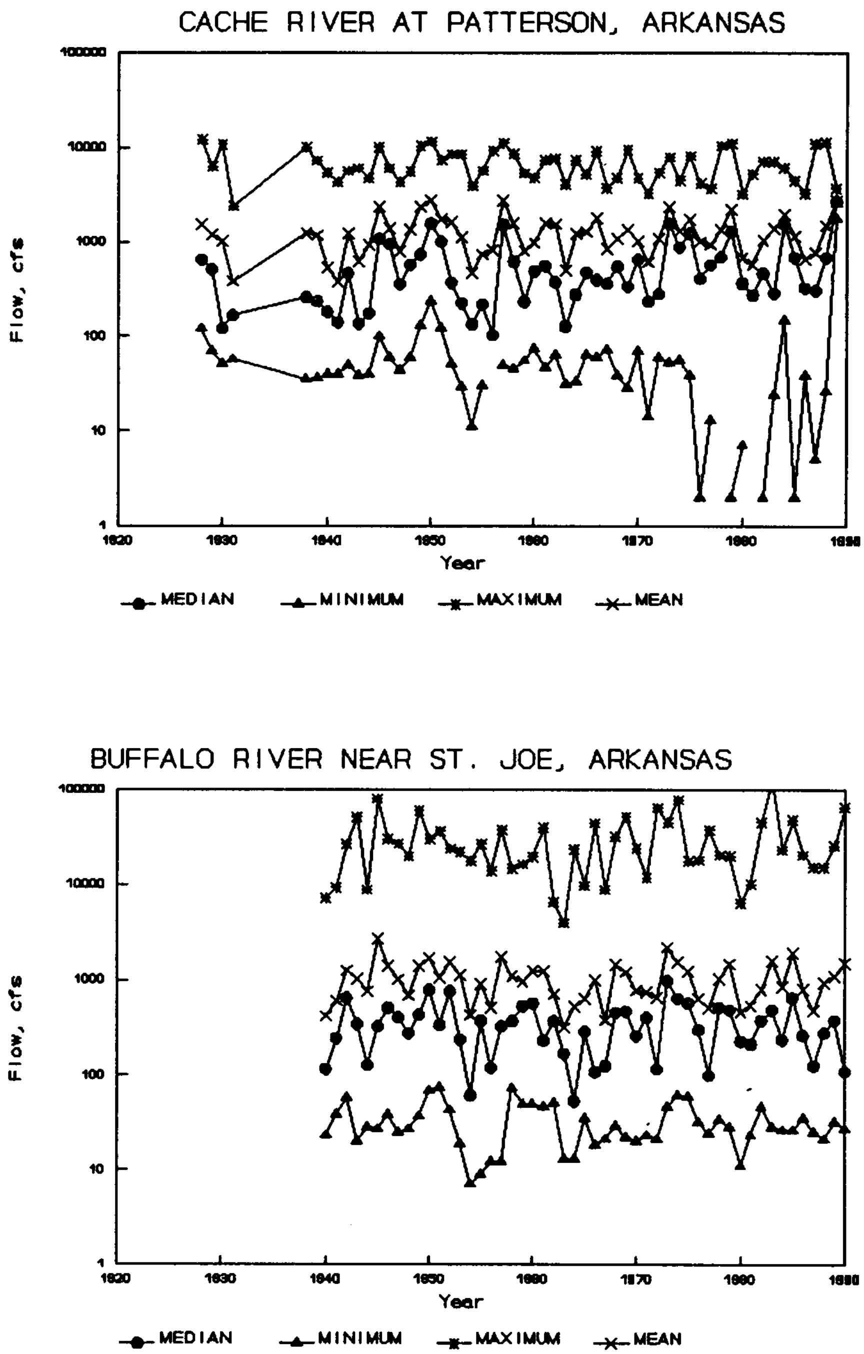
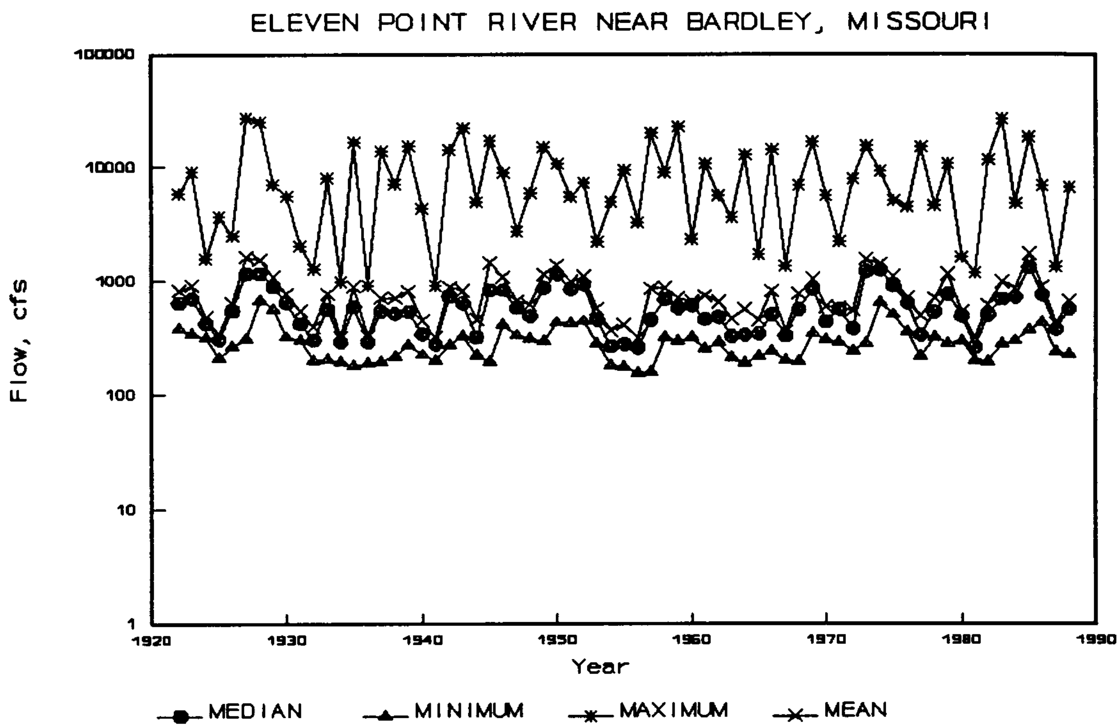


Figure 1. Yearly medians, minima, maxima, and means of selected steamflows in the White River Basin (Arkansas/Missouri). Note that the scale of flow is logarithmic and that recording periods do not include some years



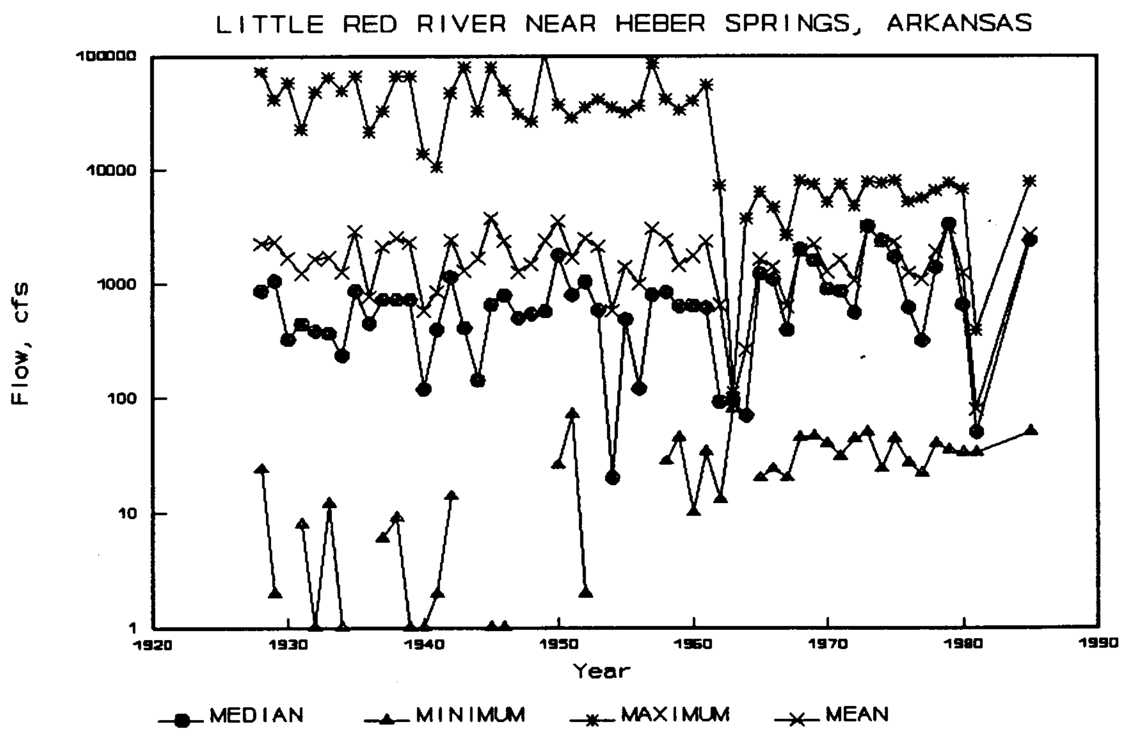


Figure 1. (Concluded)

- Of this resulting set of means, the mean, minimum, and maximum for each month in each decade were determined.

- Cosine curves were fit to the mean, minimum, and maximum values, respectively, for each decade using the PROC NLIN routine (SAS 1988).

- This procedure provided the coefficients (phase, amplitude) with period of one year used to produce the curves in Figures 2 to 5 corresponding to the respective months of the year.

Harmonic analysis also is convenient to compare flow patterns of rivers in the same or nearby watersheds, possibly permitting inference of regional or global effects. Figures 2 to 5 show results of the application of the harmonic analysis technique to the four streams presented in Figure 1. The minimum flow curves for each decade describing the Cache River reveal the progressive changes in both phase and amplitude, being conspicuous in the decade 1961-70. It should be noted that the cosine approximation may not always yield the "best" fit to the data compared to some other model.

In contrast, the harmonic analysis of the daily flow records of the Buffalo River (Fig. 3) reveals no similar deviation from the cosine function, while a corresponding analysis of the Eleven Point River (Fig. 4) shows a fairly consistent relationship between maximum means and means from decade to decade, with a "flatter" curve representing the minimum means in all decades but that of 1951-60. The record of the Little Red River (Fig. 5) reveals extreme fluctuation of the minimum monthly means until the decade of 1961-70, when the minimum curve became quite flat by comparison. These comparisons indicate that one or more fundamental changes occurred in the stream and/or basin either during the time period in question or in prior years (delayed effect) and these warrant further study. This easily observed phenomenon corresponds with the time of complete regulation of the stream to form Greers Ferry Lake, demonstrating the method to be sensitive to at least extreme events.

The ratio of the amplitude (estimated using PROC NLIN) to the corresponding mean (minimum, maximum, or median) of monthly flows for the time period of interest, can be used to summarize the strength of the seasonal pattern (*"seasonality index,"* modified from Nestler 1993). Higher values of this ratio indicate stronger seasonality in the flows, whereas lower values indicate unpredictability, or randomness, which is not necessarily dependent on season of the year. Figure 6 shows the Eleven Point River with low values of the index throughout its time period, whereas the values of the indices of the Cache River and the Little Red River generally decline with passing years. The seasonality indices for the maxima, minima, and medians are also shown to permit comparison of these statistics as well. Note that highest seasonality index values were obtained for the minima (compared to the other three statistics considered) for all streams except for the Eleven Point River.

CONCLUSION: Harmonic analysis is one technique for assessing cumulative impacts on wetlands. Streamflow (as well as groundwater) records available in many locales often span many years and may provide insight in definition of present wetlands whose current conditions have been dictated, at least in part, by these historic water conditions. In conjunction with land-use practice histories and remote sensing records of past conditions, these tools can contribute to cumulative impact analysis integral to overall planning, management, and protection of valuable and dwindling wetland resources.

Data provided by EarthInfo, Inc., US Geological Survey, and the US Army Engineer Districts were used in the formulation and validation of the techniques presented.

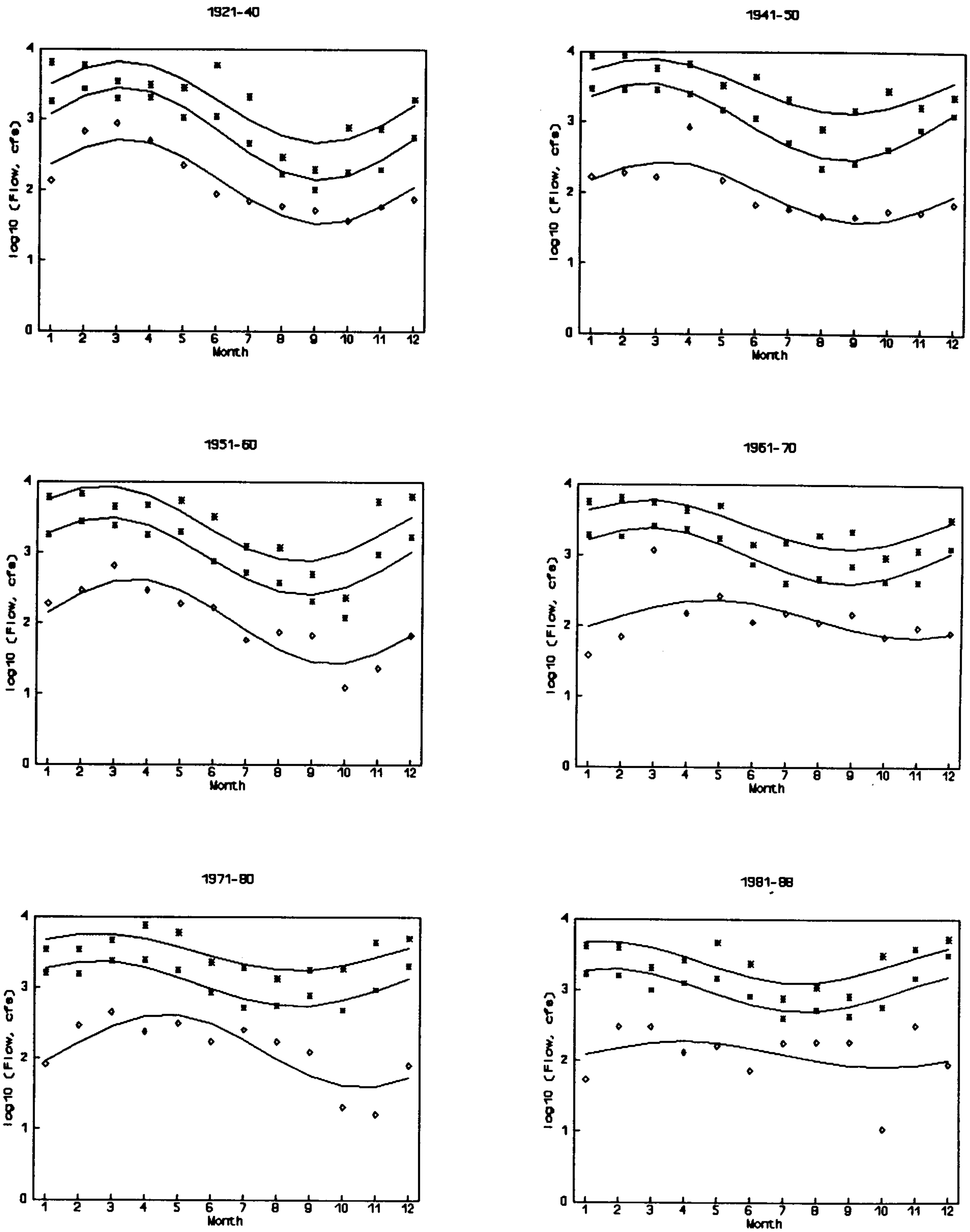


Figure 2. Harmonic analysis of the Cache River at Patterson, Arkansas

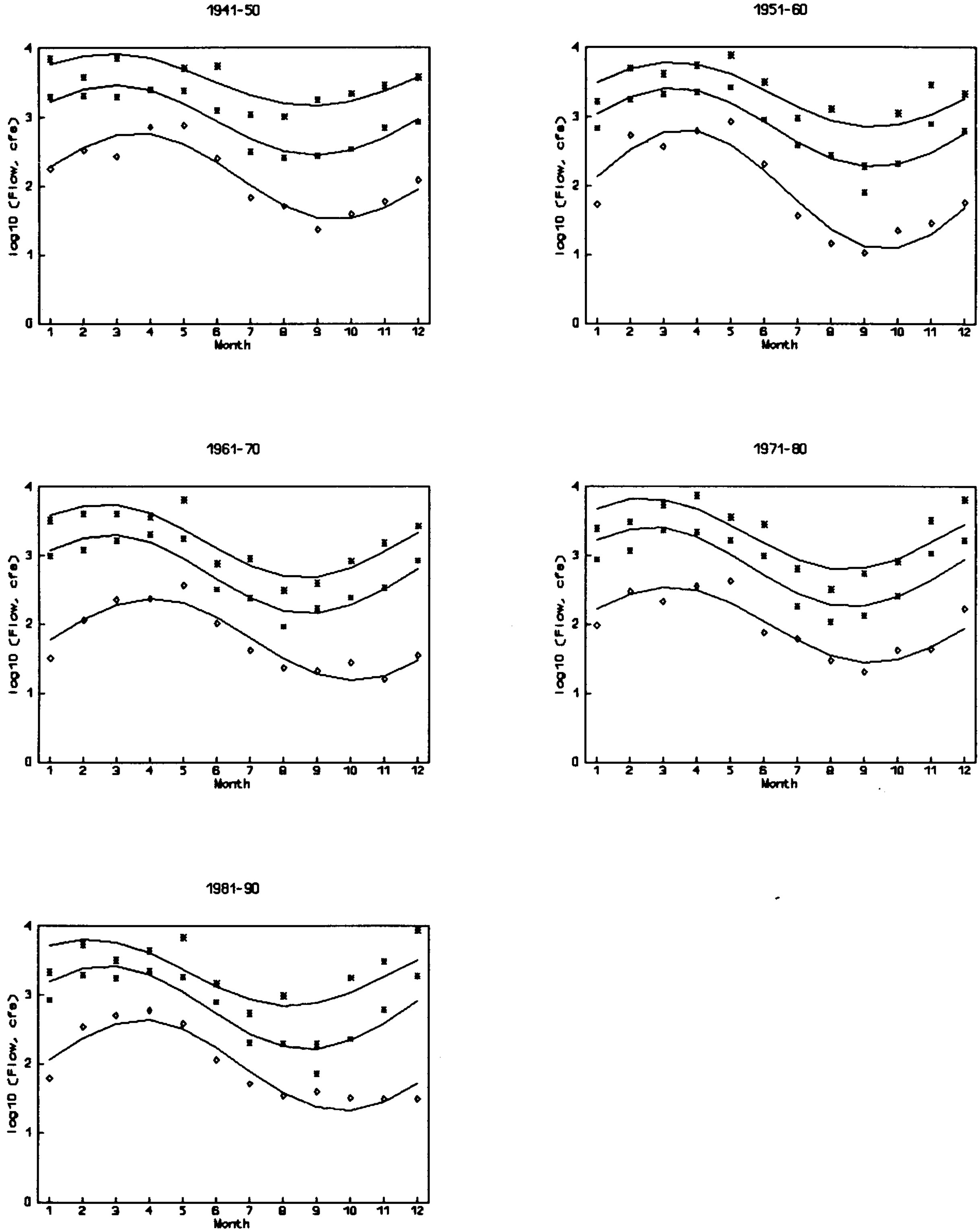


Figure 3. Harmonic analysis of the Buffalo River near St. Joe, Arkansas

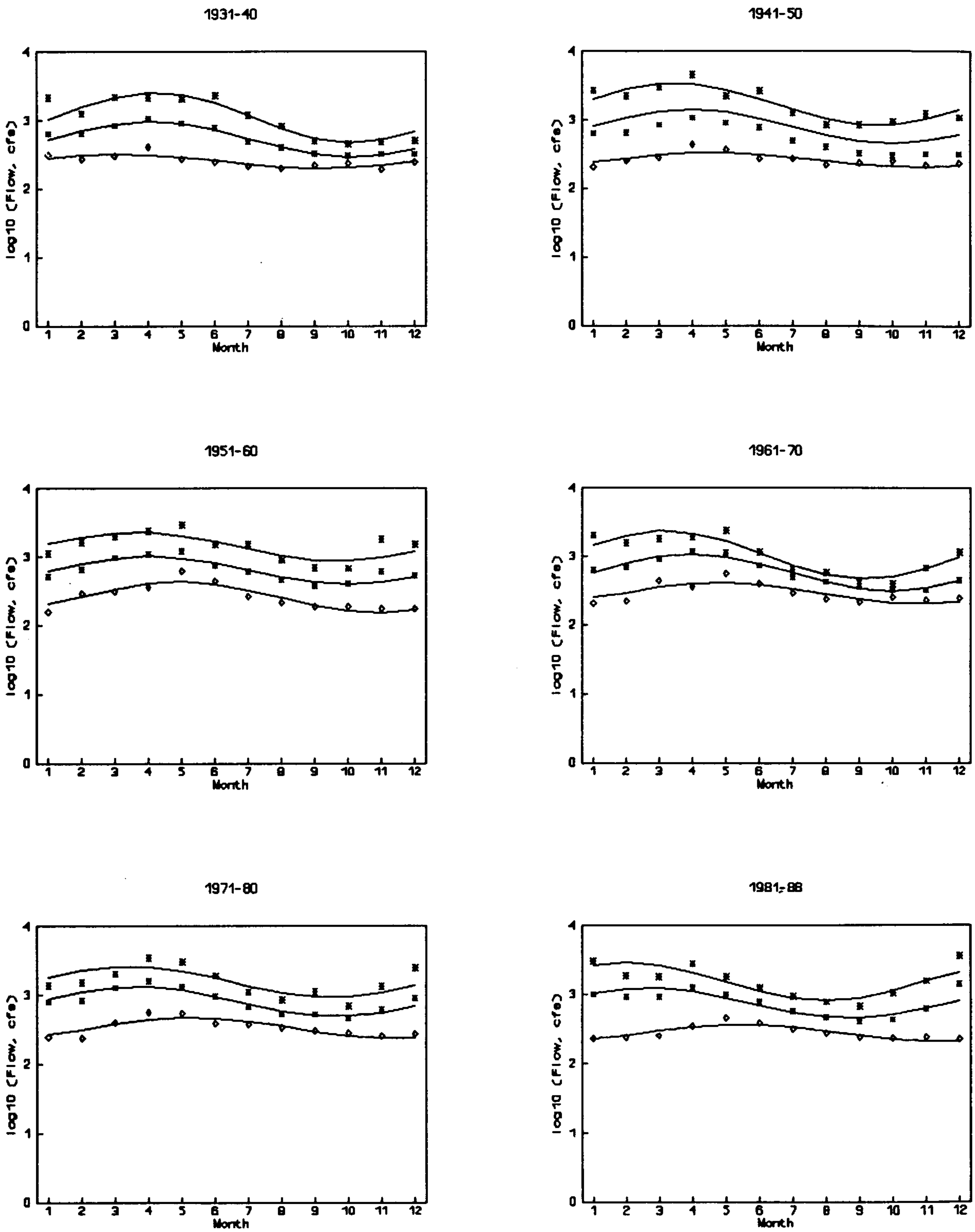


Figure 4. Harmonic analysis of the Eleven Point River near Bardley, Missouri

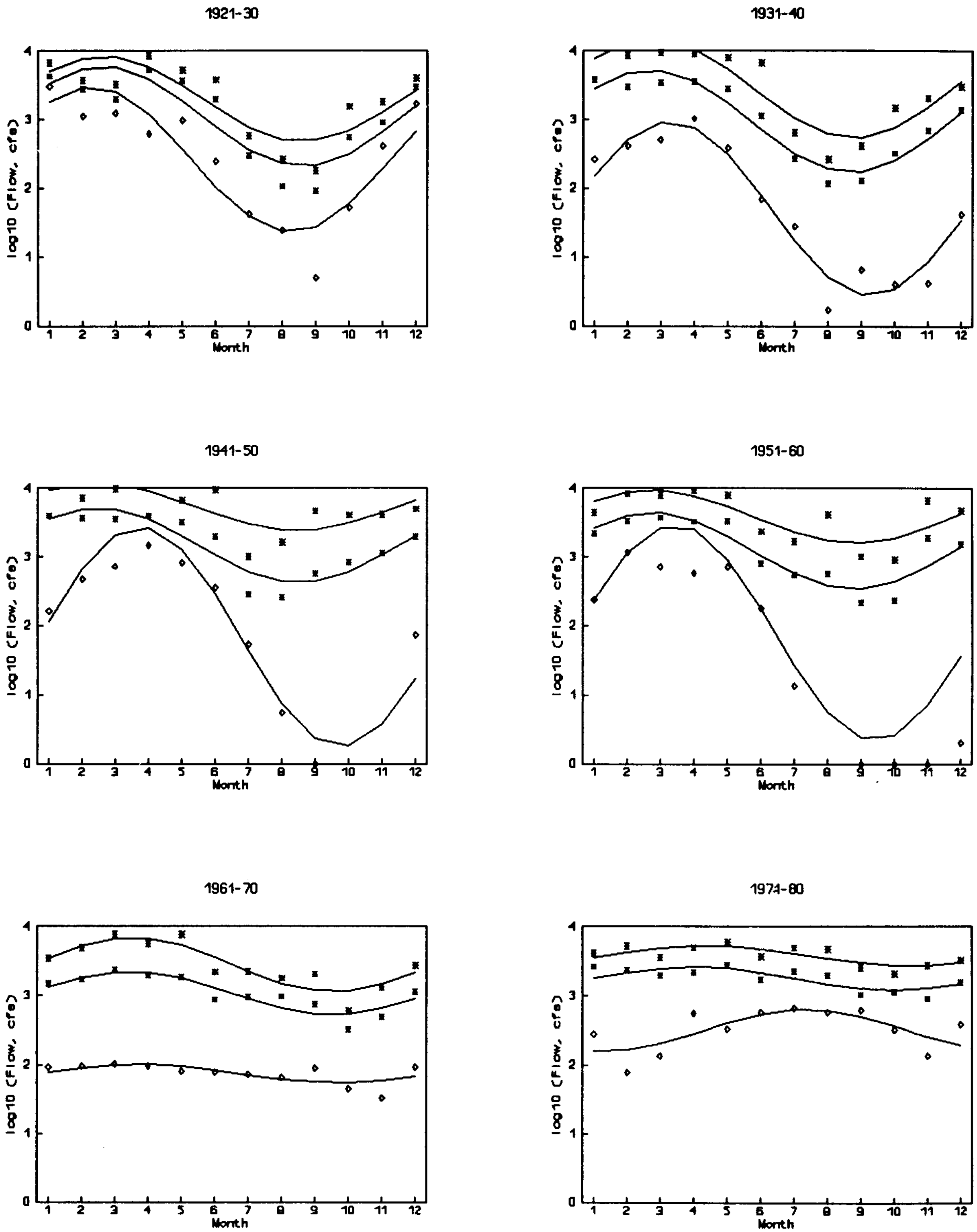


Figure 5. Harmonic analysis of the Little Red River near Heber Springs, Arkansas

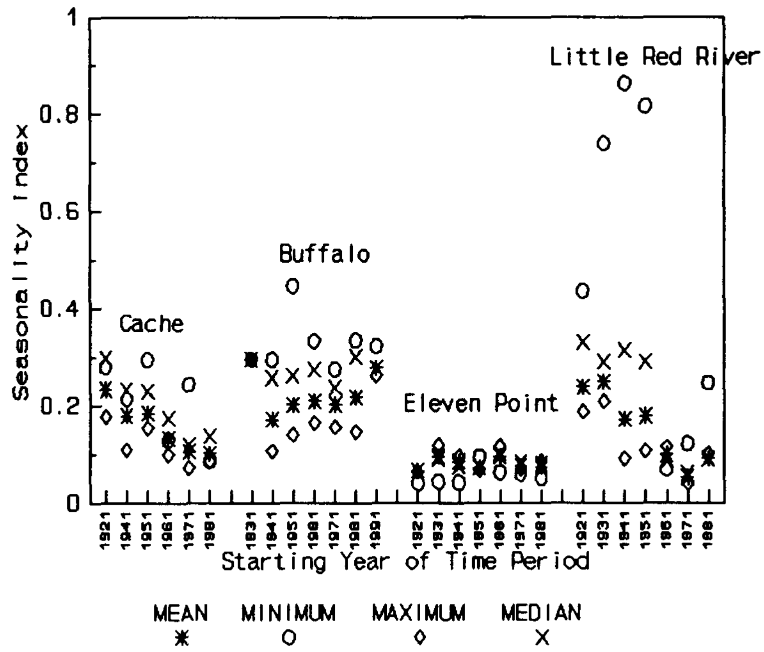


Figure 6. Seasonality indices of means, minima, maxima, and medians compared for four gages in the White River Basin, Arkansas/ Missouri

REFERENCES:

Kleiss, B. A. 1993. "Cache River, Arkansas: studying a bottomland hardwood (BLH) wetland ecosystem." Vol 3, No. 1. The Wetlands Research Program, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Long, K. S. and Nestler, J. M. *March* 1994. "Assessing cumulative impacts on wetlands: Applying time-scale analysis to hydrologic data," Wetlands Research Program Technical Note HY-IA-2.2.

Nestler, J. M. 1993. "Instream flow incremental methodology: a synopsis with recommendations for use and suggestions for future research," Technical Report EL-93-3, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Nestler, J. M. and Long, K. S. 1994. "Framework for cumulative impact analysis of wetlands using hydrologic indices," Technical Report WRP-SM-3, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

SAS Institute Inc. 1988. "PROC NLIN" (computer program), IBM-PC, SAS Institute Inc., Cary, NC.

POINT OF CONTACT FOR ADDITIONAL INFORMATION: Katherine S. Long, U.S. Army Engineer Waterways Experiment Station, ATTN: CEWES-ES-P, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, phone: (601) 634-3521, author.